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Gamma-Ray Bursts

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Black Hole Models for Gamma-Ray Bursts

This grant deals with the production of Gamma-Ray Bursts (GRBs) close to horizons of Black Holes (BHs), mainly via accretion of small chunks of matter onto extreme Kerr BHs. Since the time that we have proposed this work we were informed of an analysis of temporal characteristics of bursts which, combined with data on energies and spectra, may indicate a certain time dilation effect in them of the kind one may expect either from a cosmological distribution *or* a distribution around a BH horizon. If confirmed, that would naturally provide even stronger motivation to follow our proposal through, in addition to the motivation provided by the fact that preliminary model calculations give spectra which look remarkably similar to the average GRB spectrum.

In the past year we laid the ground work for actual calculations close to Kerr BHs. Because of technical reasons (mostly the inavailability of the graduate students selected as most suitable for this work prior to April 1993 because of prior commitments), actual work has only started very recently (and we therefore requested that the use of the award funds that we have received will be postponed and only begins now).

Following the detailed list of research subprojects as per our original proposal, we have done the following:

- (i) *Spectrum Calculations.* We are in an advanced stage of reconstructing and improving the Monte Carlo code that was used in our work from 1975. This

code allows for calculations, in an optically thin environment, of the spectrum of photons scattered in a Compton-Penrose process in the vicinity of the horizon of a Kerr BH, once the distribution of scattering electrons and of initial photons is given. In parallel, we are developing some analytical expressions that would provide a better insight into the characteristics of the whole process.

- (ii) *Burst Dynamics.* Various general considerations seem to be able to put severe constraints on burst dynamics, mainly because the observed spectrum contains a sufficient amount of $\gtrsim 1$ MeV photons that, when allowed to collide with each other, will pair-produce copiously such that (non-observed) optically *thick* situations will ensue and the emergent spectrum would thermalize. This brings about the baryon problem: one cannot afford too many of those moving at extreme relativistic speeds, a possible way to avoid too many photon-photon collisions, because they would then contain much more energy than the photons and the overall energy requirements for the process would rise to uncomfortable levels. Other constraints include the relevant timescales, which limit the sizes of candidate regions of formation.

Several possible ways out of this were proposed, none fully satisfactory. We are now looking at situations in which the geometry remains, indeed, optically thin (optical depth of order unity or less for the collisions in question) because of strong clumping and directional inhomogeneities. We have begun to sort out possible flow geometries that would give such inhomogeneities as well as the short timescales involved, in the context of an asteroid breaking up and falling into a $10 - 30 M_{\odot}$ extreme Kerr BH. On first analysis, it seems that appropriate turbulent scenarios may exist to satisfy the model requirements, but we are not

yet clear as to the conditions under which they are formed.

- (iii) *Tidal Capture* and (iv) *Primordial Cloud Collapse*. Our preliminary conjecture seems to work, but we came up with another constraint on the whole process, which is that collapsing primordial halos will produce a strong optical signal which should better not exceed what one observes (as Quasars, e.g.). This constraint is comparable to the one about Z contamination (mentioned in our original proposal), and would require still a larger asteroid fraction (by mass) than that of the Solar system, as well as rotating primordial clouds.
- (v) *Halo Density Profile*. We have begun a systematic classification of halo density models that reproduce the observed $\log N - \log S$ curves as well as the possible bi-modal distribution recently reported. It is clear that GRB sources cannot account for *all* of the dark matter in the halo.
- (vi) *Capture of Other Objects*. Cosmological BH capture scenarios (of Neutron Stars, say) are occurring at huge optical depths and the origin of the observed spectra is still a great mystery. Furthermore, the capture process may occur at smooth hydrodynamic flow with no sufficiently high temperatures forming to account for the high energy tail of the observed spectra. We are inclined more and more to prefer non optically-thick scenarios (therefore capture of smaller objects like asteroids).